OPTMIZATION OF MOLDING PARAMETER EFFECT TO WARPAGE AND SHRINKAGE OF LABORATORY GOGGLE BASED ON PLASTIC FLOW SIMULATION SOFTWARE

MOHD ‘AFIF B ABD AZIZ

Thesis submitted in partial fulfilment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering with Manufacturing Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

NOVEMBER 2010

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Manufacturing Engineering.

Signature :

Name of Supervisor: En. Mohamed Reza Zalani Bin Mohamed Suffian

Position : Lecturer
Faculty of Mechanical Engineering
University Malaysia Pahang

Date : 6 December 2010

STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature :

Name : Mohd 'Afif b Abd Aziz

ID Number : ME07057

Date : 6 December 2010

Special thanks to my parents on their support and cares,

En. Abd. Aziz B Mohd Nor

Pn. Rohani Bt Abu Bakar

Also for my siblings.

Special dedications for my supervisor,

En. Mohamed Reza Zalani Bin Mohamed Suffian

On his guiding towards my project

ACKNOWLEDGEMENTS

I am grateful and would like to express my sincere gratitude to my supervisor Mr. Mohamed Reza Zalani Bin Mohamed Suffian for his germinal ideas, invaluable guidance, continuous encouragement and constant support in making this research possible. He has always impressed me with his outstanding professional conduct, his strong conviction for science, and his belief that a PhD program is only a start of a life-long learning experience. I appreciate his consistent support from the first day I applied to finished the program to these concluding moments. I am truly grateful for his progressive vision about my training in science, his tolerance of my naïve mistakes, and his commitment to my future career.

My sincere thanks go to all my lab mates and members of the staff of the Mechanical Engineering Department, UMP, who helped me in many ways and made my stay at UMP pleasant and unforgettable. Many special thanks go to member engine research group for their excellent co-operation, inspirations and supports during this study.

I acknowledge my sincere indebtedness and gratitude to my parents for their love, dream and sacrifice throughout my life. I am also grateful to my brother, and sister for their sacrifice, patience, and understanding that were inevitable to make this work possible. I cannot find the appropriate words that could properly describe my appreciation for their devotion, support and faith in my ability to attain my goals. Special thanks should be given to my committee members. I would like to acknowledge their comments and suggestions, which was crucial for the successful completion of this study.

ABSTRACT

This thesis is about how to optimization of molding parameter effect to warpage and shrinkage. The product that will be use is laboratory goggle. The objective of this thesis is to analyze the parameters effect in injection molding to warpage and shrinkage of laboratory goggle and to determine the optimization of molding parameter effect to warpage and shrinkage of laboratory goggle during injection molding based on plastic flow simulation software. The thesis describes the moldflow software how to analyze frame and glass of laboratory goggle to identify the parameter effect to warpage and shrinkage of the product .. It need to scanning the frame and the glass of laboratory goggle and it need to use a 3D scanner machine. Then, transfer the shape and result to the solidwork software and find the dimension of the frame and glass to draw a new shape using solidwork software. Next, import the frame and glass from solidwork to the moldflow software and analyze the product. Make a optimization of the product from warpage and shrinkage. In this project, parameter in injection molding of laboratory goggle needs to define. The parameter includes mold temperature, melt temperature, injection time, and packing pressure. According to result from moldflow software, in conclusion the factor that influence the molding process it is pressure, temperature, molding temperature, molding cool must be in a correct position because it will be give a effect if the factor is not suitable.

ABSTRAK

Tesis ini adalah tentang bagaimana pengaruh cetakan mengoptimuman parameter untuk melenting dan menyusut. Produk yang akan digunakan adalah goggle makmal. Tujuan tesis ini adalah untuk menganalisis pengaruh parameter dalam cetak suntikan untuk melenting dan menyusut goggle makmal dan menentukan optimas kesan cetakan parameter untuk melenting dan menyusut goggle makmal selama injection molding didasarkan pada perisian simulasi aliran plastik. Tesis ini menjelaskan perisian moldflow bagaimana menganalisis bingkai dan kaca goggle makmal untuk mengetahui pengaruh parameter untuk melenting dan penyusutan produk .Hal ini perlu mengimbas bingkai dan kaca goggle makmal dan perlu menggunakan mesin pengimbas 3D. Kemudian, pemindahan bentuk dan hasilnya ke perisian solidwork dan mendapati dimensi dari bingkai dan kaca untuk menggambar bentuk baru menggunakan perisian solidwork. Selanjutnya, ambil sampel bingkai dan kaca dari solidwork ke perisian moldflow dan menganalisis produk. Buatlah optimalisasi produk dari melenting dan penyusutan. Dalam projek ini, parameter dalam cetakan suntikan goggle makmal perlu untuk ditakrifkan. Parameter ini meliputi suhu mold, meleleh suhu, masa suntikan, dan tekanan pembungkusan. Berdasarkan hasil dari perisian moldflow, dalam kesimpulan faktor yang mempengaruhi proses pencetakan itu tekanan, suhu, suhu molding, sejuk molding harus berada dalam kedudukan yang betul kerana akan memberikan kesan jika faktor tersebut tidak sesuai.

TABLE OF CONTENTS

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Injection molding is a critical component fabrication technique in medical device manufacturing. Therefore, any method that can be employed to reduce costs associated with it is of much interest to device makers. This article examines how principles of lean manufacturing can be used in injection molding processes to eliminate waste and reduce costs.

In recent years, plastics have begun to show great commercial potential, especially in manufacturing micro structured parts. Injection molding is the most important process to manufacture plastic parts. While many prototype plastic micro devices are fabricated using precision engineering methods, such as laser machining, microinjection molding is currently being investigated all over the world. An important advantage is that injection molding with complex geometries becomes available in one automated production step.

Then, for part warpage, either soon after molding or at some time in-service, is a problem Frequently experienced by injection molders and, at times, also by extruders. Similar to Mold shrinkage, the causes and control of warpage are closely related to inherent Material characteristics and the laws of heat transfer. In this Technical Tip, it will explain the causes and general guidelines to minimize warpage. It should be noted that warpage, like mold shrinkage, is a very complex mechanism and many factors, other than those mentioned here, have an effect on warpage. In some cases, a specific variable may have a different effect depending on other factors present.

1.2 PROJECT BACKGROUND

Injection molding is used to create many things such as wire spools, packaging, bottle caps, automotive dashboards, pocket combs, and most other plastic products available today. Injection molding is the most common method of part manufacturing. It is ideal for producing high volumes of the same object. Some advantages of injection molding are high production rates, repeatable high tolerances, the ability to use a wide range of materials, low labour cost, minimal scrap losses, and little need to finish parts after molding. Some disadvantages of this process are expensive equipment investment, potentially high running costs, and the need to design moldable parts.

1.3 PROJECT OBJECTIVE

I) Analyze the parameters effect in injection molding to warpage and shringkage of laboratory goggle.

II) To determine the optimization of molding parameter effect to warpage and shringkage of laboratory goggle during injection molding based on plastic flow simulation software.

1.4 PROJECT SCOPE

For this project, a lot of information can be find and study about the title. Find the information from the journals, internet, books, article and other resources. And as a student needed guidance from the supervisor to make sure that project that we do is connect with our title and objective of project. The knowledge will apply in the project until it is complete.

This project needs a long time to doing step by step to get an information until the analyzes is complete in the last step. In this project, the object is to analyze a laboratory goggle. So, it will use a 3D scanner as a first step to get the accurate dimension of laboratory goggle. It is a reverse engineering to study the injection molding product in Faculty of Mechanical (FKM) Laboratory in Pekan Gambang.

For the 3D scanner from FKM lab, it can using a CIMCORE INFINITE 2.0 as a device which is can analyzes a real world object and collect as many data on the object's shape and appearance included colour.

After that, it need use software like solid work to draw the laboratory goggle with the accurate dimension and size. That's why it need to do a scanning. The advantage by using a solid work to draw the real laboratory goggle is it can get 100% dimension and size in the result.

In the last step of this project, use a Moldflow Software to make the analyze to the parameter of laboratory goggle. Moldflow Corporation's two core products are Moldflow Plastics Insight and Moldflow Plastics Advisers. One of the product will be used.

1.5 PROBLEM STATEMENT

In this project, parameter in injection molding of laboratory goggle needs to define. The parameter includes mold temperature, melt temperature, cooling time, and injection pressure. Base on research, 4 parameters was choice to make the analysis in order to make the optimization of molding parameter and minimize the warpage and shrinkage of laboratory goggle based on plastic flow simulation software. The parameters are mold temperature, melt temperature, packing pressure and injection time.

The parameter need to make analysis base on plastic flow simulation software. In this project, MoldFlow Plastic Insight was use to make the analysis on parameter chosen. The analysis includes warpage and shrinkage in laboratory goggle. From that, it's important to optimize the parameter in order to minimize warpage and shrinkage.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This project title is optimization of molding parameter effect to warpage and shrinkage of laboratory goggle based on plastic flow simulation software. Optimization definition is the procedure or procedures used to make a system or design as effective or functional as possible, especially the mathematical techniques involved. So, optimization of molding parameter is to make improvement about the molding parameter that effect to warpage in injection molding.

Injection molding is a manufacturing process for producing parts from both thermoplastic and thermosetting plastic materials. Material is fed into a heated barrel, mixed, and forced into a mold cavity where it cools and hardens to the configuration of the mold cavity. After a product is designed, usually by an industrial designer or an engineer, molds are made by a mold maker (or toolmaker) from metal, usually either steel or aluminum, and precision-machined to form the features of the desired part. Injection molding is widely used for manufacturing a variety of parts, from the smallest component to entire body of cars.

2.2 INJECTION MOLDING

Making polymers is a fantastic science. Then there is the matter of shaping the plastic into useful objects another fantastic science. One of the most common methods of shaping plastic resins is a process called injection molding. Injection molding is accomplished by large machines called injection molding machines.

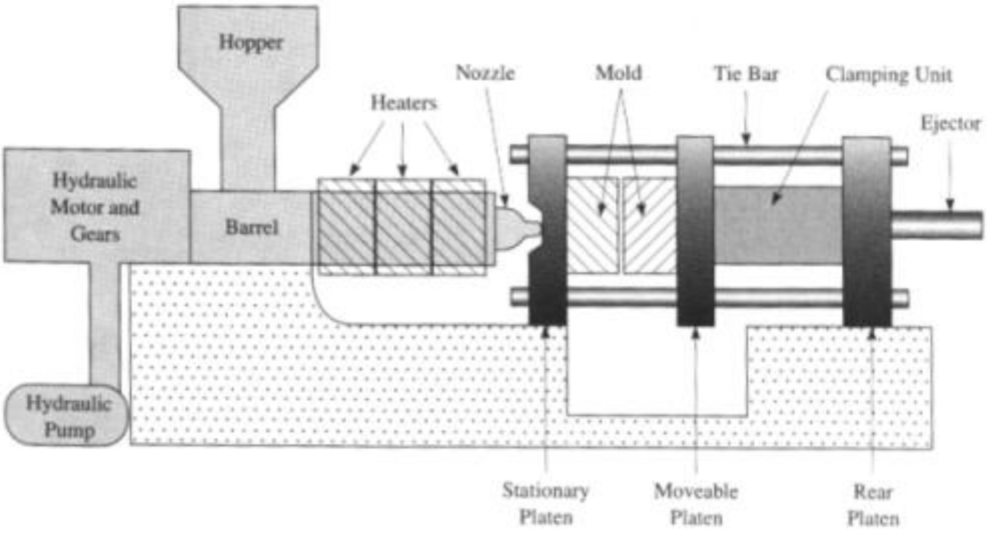

Figure 2.1: Injection molding process

Source : A. Brent Strong 2003

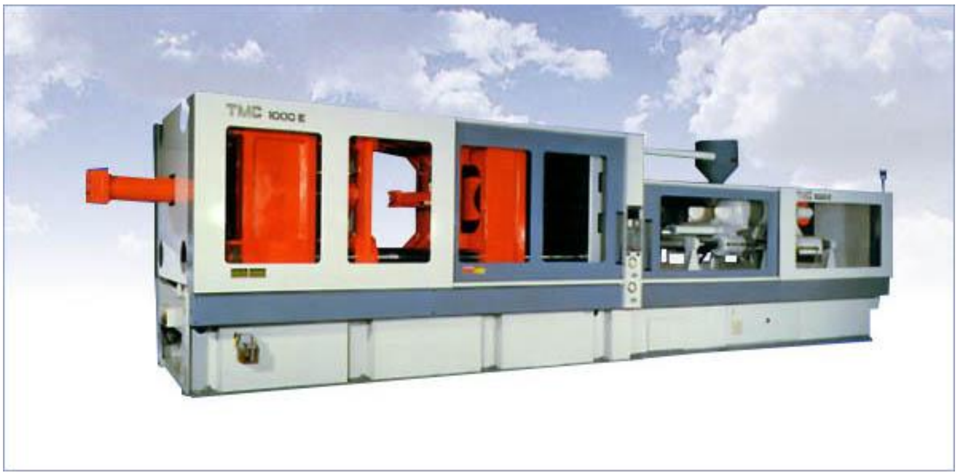

Figure 2.2: injection molding machine

Source : A. Brent Strong 2003

Resin is fed to the machine through the hopper. Colorants are usually fed to the machine directly after the hopper. The resins enter the injection barrel by gravity though the feed throat. Upon entrance into the barrel, the resin is heated to the appropriate melting temperature.

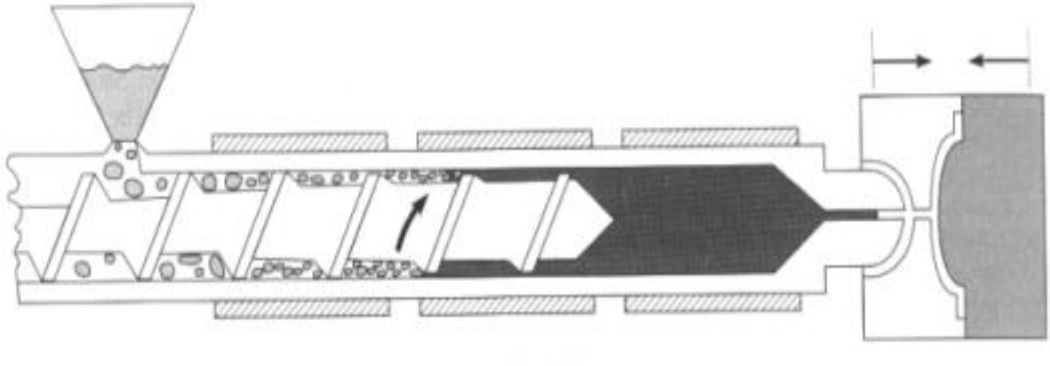

Figure 2.3: Process at hopper and heater

Source : A. Brent Strong 2003

The resin is injected into the mold by a reciprocating screw or a ram injector. The reciprocating screw apparatus is shown above. The reciprocating screw offers the advantage of being able to inject a smaller percentage of the total shot (amount of melted resin in the barrel). The ram injector must typically inject at least 20% of the total shot while a screw injector can inject as little as 5% of the total shot. Essentially, the screw injector is better suited for producing smaller parts.

The mold is the part of the machine that receives the plastic and shapes it appropriately. The mold is cooled constantly to a temperature that allows the resin to solidify and be cool to the touch. The mold plates are held together by hydraulic or mechanical force. The clamping force is defined as the injection pressure multiplied by the total cavity projected area. Typically molds are overdesigned depending on the resin to be used. Each resin has a calculated shrinkage value associated with in.

Injection molding is used to create many things such as wire spools, packaging, bottle caps, automotive dashboards, pocket combs, and most other plastic products available today. Injection molding is the most common method of part manufacturing. It is ideal for producing high volumes of the same object. Some advantages of injection molding are high production rates, repeatable high tolerances, the ability to use a wide range of materials, low labour cost, minimal scrap losses, and little need to finish parts after molding. Some disadvantages of this process are expensive equipment investment, potentially high running costs, and the need to design moldable parts.

2.3 SHRINKAGE

Shrinkage is inherent in the injection molding process. Shrinkage occurs because the density of polymer varies from the processing temperature to the ambient temperature (see Specific volume (pvT diagram)). During injection molding, the variation in shrinkage both globally and through the cross section of a part creates internal stresses. These so-called residual stresses (see Residual stress) act on a part with effects similar to externally applied stresses. If the residual stresses induced during molding are high enough to overcome the structural integrity of the part, the part will warp upon ejection from the mold or crack with external service load.

The shrinkage of molded plastic parts can be as much as 20 percent by volume, when measured at the processing temperature and the ambient temperature. Crystalline and semi-crystalline materials are particularly prone to thermal shrinkage; amorphous materials tend to shrink less. When crystalline materials are cooled below their transition temperature, the molecules arrange themselves in a more orderly way, forming crystallites. On the other hand, the microstructure of amorphous materials does not change with the phase change. This difference leads to crystalline and semi-crystalline materials having a greater difference in specific volume between their melt phase and solid (crystalline) phase. This is illustrated in Figure 1 below. We'd like to point out that the cooling rate also affects the fast-cooling pvT behavior of crystalline and semi-crystalline materials.

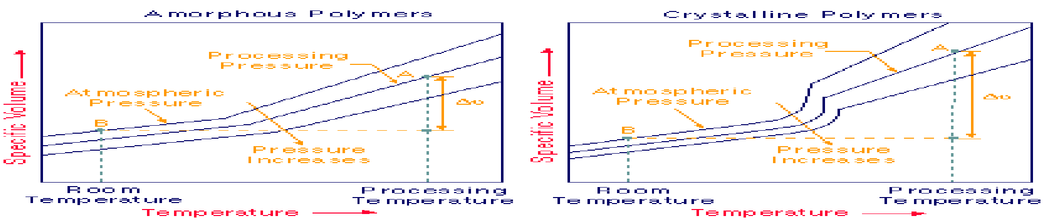

FIGURE 2.4 : The pvT curves for amorphous and crystalline polymers and the specific volume variation between the processing state (point A) and the state at room temperature and atmospheric pressure (point B). Note that the specific volume decreases as the pressure increases.

Source : Thomas L. (1995)

2.3.1 Shrinkage (accounting) – The loss of products

In financial accounting the term inventory shrinkage (sometimes truncated to shrink) is the loss of products between point of manufacture or purchase from supplier and point of sale. The term shrink relates to the difference in the amount of margin or profit a retailer can obtain. If the amount of shrink is large, then profits go down which results in increased costs to the consumer to meet the needs of the retailer. The total shrink percentage of the retail industry in the United States was 1.52% of sales in 2008 according to the University of Florida's, National Retail Security Survey. In Europe shrinkage was about 1.27% of sales and the same figure for Asia Pacific was 1.20% .

2.3.2 Shrinkage (statistics) – A technique to improve an estimator

In statistics, shrinkage has two meanings:

I) In relation to the general observation that, in regression analysis, a fitted relationship appears to perform less well on a new data set than on the data set used for fitting. In particular the value of the coefficient of determination 'shrinks'. This idea is complementary to overfitting and, separately, to the standard adjustment made in the coefficient of determination to compensate for the subjunctive effects of further sampling, like controlling for the potential of new explanatory terms improving the model by chance: that is, the adjustment formula itself provides "shrinkage." But the adjustment formula yields an artificial shrinkage, in contrast to the first definition.

II) To describe general types of estimators, or the effects of some types of estimation, whereby a naive or raw estimate is improved by combining it with other information.: see shrinkage estimator. The term relates to the notion that the improved estimate is at a reduced distance from the value supplied by the 'other information' than is the raw estimate. In this sense, shrinkage is used to regularize ill-posed inference problems.

A common idea underlying both of these meanings is the reduction in the effects of sampling variation.

2.3.3 Shrinkage (casting) – A casting defect brought about by the reduction in volume of the cast material as it cools and solidifies

In metalworking, casting involves pouring a liquid metal into a mold, which contains a hollow cavity of the desired shape, and then is allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mold to complete the process. Casting is most often used for making complex shapes that would be difficult or uneconomical to make by other methods.

The casting process is subdivided into two main categories: expendable and non-expendable casting. It is further broken down by the mold material, such as sand or metal, and pouring method, such as gravity, vacuum, or low pressure.

Cooling curves are important in controlling the quality of a casting. The most important part of the cooling curve is the *cooling rate* which affects the microstructure and properties. Generally speaking, an area of the casting which is cooled quickly will have a fine grain structure and an area which cools slowly will have a coarse grain structure. Below is an example cooling curve of a pure metal or eutectic alloy, with defining terminology.

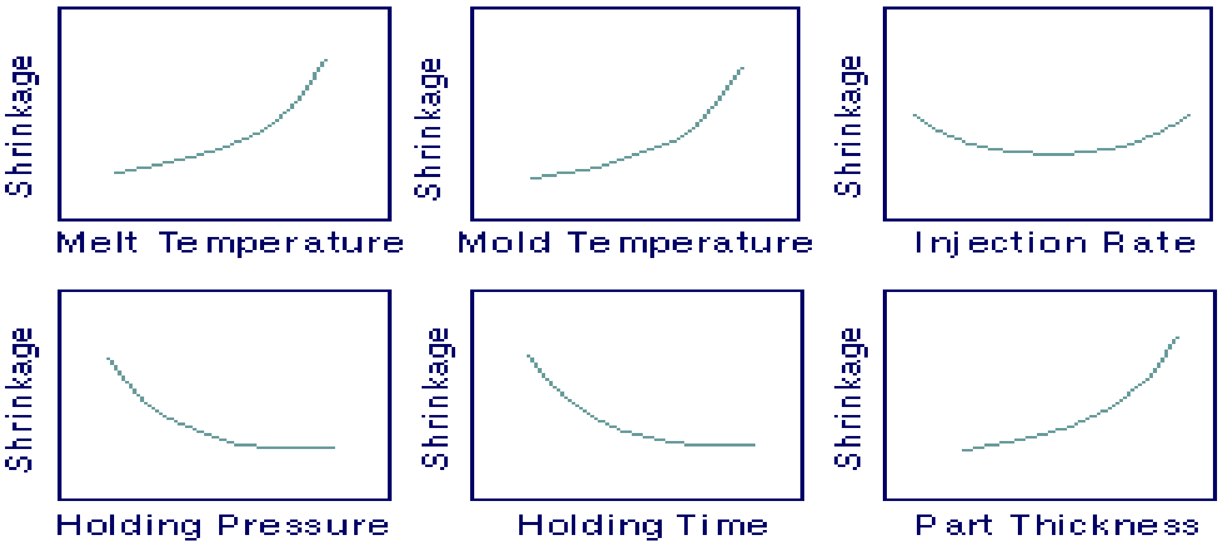

Figure 2.5: Graph of shrinkage

Source : J. Randolph 1999

Note that before the thermal arrest the material is a liquid and after it the material is a solid; during the thermal arrest the material is converting from a liquid to a solid. Also, note that the greater the superheat the more time there is for the liquid material to flow into intricate details.

The cooling rate is largely controlled by the mold material. When the liquid material is poured into the mold, the cooling begins. This happens because the heat within the molten metal flows into the relatively cooler parts of the mold. Molding materials transfer heat from the casting into the mold at different rates. For example, some molds made of plaster may transfer heat very slowly, while steel would transfer the heat quickly. Where heat should be removed quickly, the engineer will plan the mold to include special heat sinks to the mold, called chills. Fins may also be designed on a casting to extract heat, which are later removed in the cleaning (also called fettling) process. Both methods may be used at local spots in a mold where the heat will be extracted quickly. Where heat should be removed slowly, a riser or some padding may be added to a casting.

The above cooling curve depicts a basic situation with a pure alloy; however, most castings are of alloys, which have a cooling curve shaped as shown below.

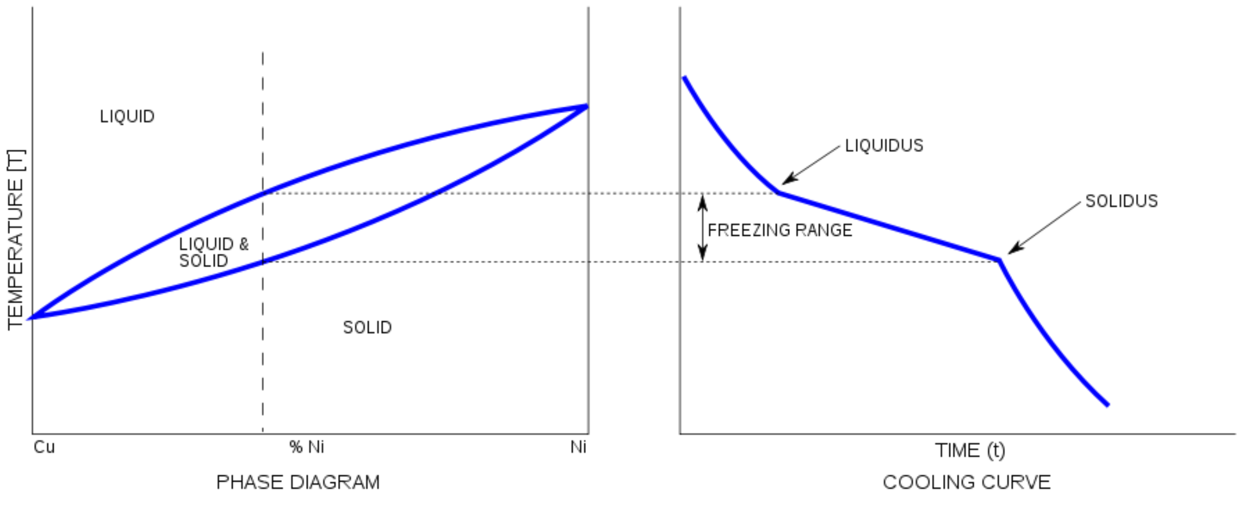

Figure 2.6: Graph of Temperature with Phase diagram and time coolong curve

Source : Meyer 1997

Note that there is no longer a thermal arrest; instead there is a freezing range. The freezing range corresponds directly to the liquidus and solidus found on the phase diagram for the specific alloy.

2.4 WARPAGE

Warpage is a distortion where the surfaces of the molded part do not follow the intended shape of the design. Part warpage results from molded-in residual stresses, which, in turn, is caused by differential shrinkage of material in the molded part. If the shrinkage throughout the part is uniform, the molding will not deform or warp, it simply becomes smaller. However, achieving low and uniform shrinkage is a complicated task due to the presence and interaction of many factors such as molecular and fiber orientations, mold cooling, part and mold designs, and process conditions.

Thick sections cool slower than thin sections. The thin section first solidifies, and the thick section is still not fully solidified. As the thick section cools, it shrinks and the material for the shrinkage comes only from the unsolidified areas, which are connected, to the already solidified thin section.

This builds stresses near the boundary of the thin section to thick section. Since the thin section does not yield because it is solid, the thick section (which is still liquid) must yield. Often this leads to warping or twisting. If this is severe enough, the part could even crack.

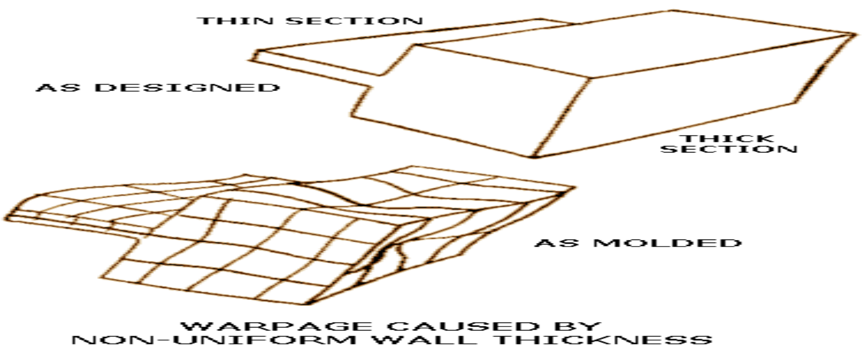

Figure 2.7: Example of warpage

Source : E. Paul 2003

Other causes:

- Warping can also be caused due to non-uniform mold temperatures or cooling rates.
- Non-uniform packing or pressure in the mold.
- Alignment of polymer molecules and fiber reinforcing strands during the mold fill results in preferential properties in the part.
- Molding process conditions--too high a injection pressure or temperature or improper temperature and cooling of the mold cavity. Generally, it is best to follow the resin manufacturer's guidelines on process conditions and only vary conditions within the limits of the guidelines.

  It is not good practice to go beyond the pressure and temperature recommendations to compensate for other defects in the mold. If runners need to be sized differently to allow for a proper fill, or gate sizes that need to be changed, then those changes need to happen.

  Otherwise the finished parts will have too much built in stresses, could crack in service or warp-leading to more severe problems such as customer returns or field service issues.

2.5 PARAMETER

In computer programming, a parameter is a special kind of variable, used in a subroutine to refer to one of the pieces of data provided as input to the subroutine. These pieces of data are called arguments. An ordered list of parameters is usually included in the definition of a subroutine, so that, each time the subroutine is called, its arguments for that call can be assigned to the corresponding parameters.

The term "argument" is often used in place of "parameter," though this is strictly incorrect. See the Parameters and arguments section for more information.

In the most common case, call-by-value, a parameter acts within the subroutine as a local (isolated) copy of the argument, but in other cases, e.g. call-by-reference, the argument supplied by the caller can be affected by actions within the called subroutine (as discussed in evaluation strategy).

The semantics for how parameters can be declared and how the arguments get passed to the parameters of subroutines are defined by the language, but the details of